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AN EXPERIMENTAL INVESTIGATION TO STUDY THE PERFORMANCE AND EMISSION CHARACTERISTICS OF n-BUTANOL-GASOLINE BLENDS IN A TWIN SPARK IGNITION ENGINE

RAVIKUMAR. R[1] & ANTONY. A. J[2]

[1]Research Scholar, Department of Mechanical and Automobile Engineering, Faculty of Engineering, CHRIST (Deemed to be University), Bangalore, Karnataka, India

[2]Principal, Mangalore Marine College and Technology, Mangalore, Karnataka, India

ABSTRACT

The need of a substitute for the fossil fuels has gained maximum importance in the recent days with the depletion of fossil fuels, increasing vehicle population, enforcement of strict pollution norms to ensure a better environment for the present and future generations. Researchers around the world have investigated many fuels for IC engines and have found that alcohols exhibit properties that closely resemble the properties of gasoline. Alcohols form a stable mixture with gasoline in almost all proportions. This property of alcohol has increased its popularity as a fuel blend with gasoline. This paper aims at presenting the performance characteristics of a twin spark ignition engine fuelled with the blends of n-butanol-gasoline. In this investigation, pure gasoline (B00) and blends of gasoline with n-Butanol forms the fuel for twin spark ignition engine. The use of B35 blend, lower carbon monoxide emissions, lower unburnt hydrocarbon and lower nitrogen oxide emissions are observed as compared to pure gasoline. With these investigational results, one can arrive at the conclusions that with the use of higher blends of n-butanol-gasoline, the emission of the regulated emissions are reduced and are seen to be optimal with B35 in a twin spark ignition engine.

KEYWORDS: Twin Spark Ignition, n-Butanol-Gasoline, Regulated Emissions & Combustion

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Original Article

1. INTRODUCTION

The early 18th century had witnessed a very little vehicle population and thus pollution caused by the exhaust emissions were also very less. As the days rolled on, the craze for automobiles increased and the corresponding exhaust emissions from these engines increased with the increase in the automobile population. It was only in the early 20th century that the emission norms came into existence. Since then, greater precautions are taken to prevent the environment from the harmful exhaust emissions, such as carbon monoxide, unburnt hydrocarbons and oxides of nitrogen. Adoption of many improved technologies in the automobiles is seen to cope up with the stringent emission norms. A few are the improvements in the combustion chamber design to bring about complete combustion in the cylinder, the introduction of a second spark plug into the combustion chamber for complete combustion in case of SI engines and treating the exhaust gasses before it is being actually released to the atmosphere.

Along with these engine modifications, many research works to investigate the best suitable substitute for fossil fuels were under investigation. The fuels tested were from a biological origin, as these fuels are produced easily and are inexhaustible in nature. In the research of finding a substitute for fossil fuels, alcohols emerged as one

of the best replacements for fossil fuels. Alcohols can suitably find application in both diesel engines as well as the gasoline engines. Alcohol properties are closer to the gasoline, thus finds a better application in SI engines than in the CI engines.

2. LITERATURE REVIEW

Alcohols are one of the widely preferred close substitutes for the petroleum products, as they can be produced from any vegetable biomass. The commonly employed biomass for the production of the alcohol is the corn, barley, sugar cane, sweet sorghum, sugar beets agricultural leftovers. In the process of preparation of alcohols, the biomass is subjected to fermentation [1, 2, 3 & 4]. Among the alcohols that are employed as fuels in internal combustion engines, methanol is the only alcohol that does not have a biomass origin, but is being produced from the fossil fuels like the coal or from any other petroleum-based fuels. Ethanol is a biofuel that is produced from the fermentation of biomass [5, 6 & 7]. Though ethanol is widely gaining its popularity as an IC engine fuel, it has certain limitations that limit its use in IC engines, such as the hygroscopic nature, highly reactive nature and lower energy potential.

A solution to these problems was given with the emergence of butanol. Butanol is a compound having four carbon atoms. Butanol has four isomers, as the n-Butanol or the normal butanol, 2-Butanol, iso-butanol and terc-butanol. Out of these four isomers, n-butanol and the iso-butanol are found to be the most suitable substitutes for the gasoline [6, 8]. Then butanol possesses a higher calorific value, lower latent heat, lower vapor pressure, a higher octane number and does not get contaminated with water. These properties make n-butanol as one of the best sought fuel alternatives after ethanol [8, 9, 10 & 11]. Higher boiling temperature, lower viscosity and lower vapor pressure are few limitations of using n-butanol in IC engines.

The experiments conducted by Prashanth *et al.* [8] on a twin spark plug engine using an ethanol-gasoline blend, have shown that using a single spark plug in a single-cylinder engine, the time taken by the flame front to propagate to the other corner of the cylinder is very little. In such a condition, the amount of unburnt hydrocarbons' emission of the engine increases. This can be efficiently minimised by the use of an additional spark plug at a position exactly opposite to the first spark plug. The second spark plug ejects the spark alternatively with respect to the ejection by the first spark plug [12].

The research was conducted by yang *et al.* and Gu *et al.* on butanol as fuel in an SI engine to investigate the performance and emissions. The results have shown that butanol exhibits higher resistance to knocking. It emits lesser engine emissions, such as the carbon monoxide, carbon dioxide, unburnt hydrocarbons and the nitrogen oxide derivatives as compared with the gasoline [13, 14, 15 & 16]. The engine brake torque, brake power, mechanical efficiency and volumetric efficiency have shown a significant increase with butanol.

3. EXPERIMENTAL SETUP AND METHODOLOGY

3.1 Engine Setup

The experimental setup is fabricated using a Bajaj make 220 CC, twin spark ignition engine. The engine is coupled to the eddy current generator with the help of a coupling. All necessary accessories such as the exhaust smoke analyser, crank angle sensor pressure transducer, loading unit, controlling switches, ammeter and voltmeter are assembled together as shown in figure 1. The engine specifications are listed in table 1.

3.2 Methodology

The experimentation was conducted at two different stages. In the first stage, pure gasoline was used as fuel, while in the next stage, different blends of n-butanol-gasoline were tested. The necessary readings of ammeter, voltmeter, differential manometer reading, digital tachometer reading, exhaust gas analyser, etc., were noted down by running the engine at variable load and constant speed. The same set of readings were collected for different blends, and the calculation was made.

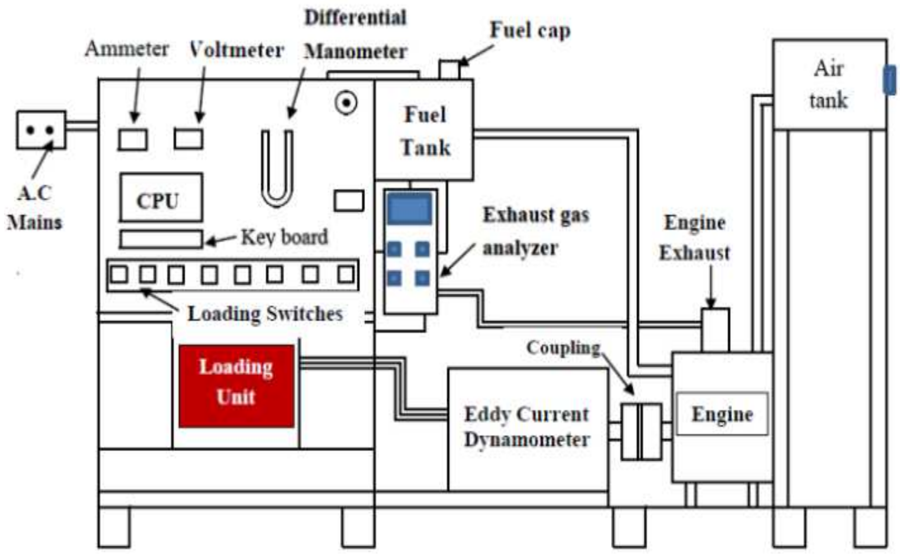

Figure 1: Experimental Test Rig.

Table 1: Engine Specifications

Parameter	Description
Engine	4-Stroke, Oil Cooled, Single Cylinder
Engine Displacement (CC)	220 CC
Power-(PS @ rpm)	20.76 bhp @ 8500 rpm
Torque-(Nm @ rpm)	19.12 Nm @ 7000 rpm
Bore diameter	67 mm
Stroke length	62.4 mm
Rated Compression Ratio	9.5:1
Number of Valves	2
Valves arrangement	Overhead Camshaft
Fuel Supply System	Carburetor
Engine Cooling System	Oil Cooled and Air-Cooled
Fuel Type	Petrol
Ignition type	Twin Spark Ignition

4. RESULTS AND DISCUSSIONS

4.1 Influence of the n-Butanol-Gasoline Blends on the Indicated Power

The developed engine test rig was tested with pure gasoline and n-butanol blends to obtain the total power generated by the engine. The results showcased that indicated power for all the blends were greater than the pure gasoline fuel. The investigation evidenced that, indicated power increases with increasing n-butanol content up to part-load condition. Total power generated by the engine started to decline, while the engine runs with a full load. The results show 0.21% of higher indicated power, which is obtained to blend B35 as compared to pure gasoline, which exhibits in figure 2.

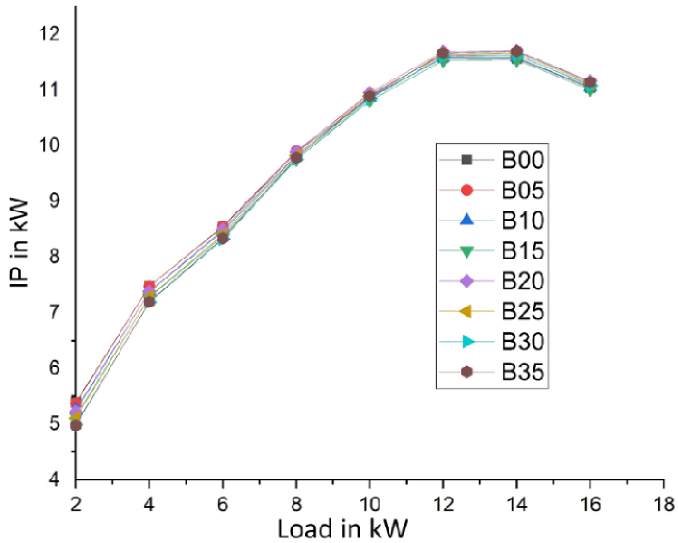

Figure 2: Influence of the n-Butanol-Gasoline Blends on the Brake Power.

4.2 Influence of the n-Butanol-Gasoline Blends on the Brake Power

The engine was tested for brake power with pure gasoline (B00) and varying blends of n-butanol and gasoline ranging from B05 to B35. The corresponding graphs for various blends of butanol-gasoline are plotted as shown in figure 3. From the charts, it is evident that with the increase of n-butanol in the blends, the brake power of the engine is also seen to be increasing. The blend B35, the BP was found to be 8.622kW and with B00, the BP was7.638 kW at a speed of 3000 rpm. In comparison with B00, B35 yielded an increase in brake power of 12.8% at the rated compression ratio of 9.5:1. The increase in brake power is accounted for due to better combustion in the engine cylinder. As the butanol percentage is increased, the hydroxyl group in n-butanol facilitates the necessary oxygen for the improved combustion process. Also, in a twin spark ignition engine, the time required for the combustion of the fuel is reduced by the additional spark plug. The spark ejected by the second spark plug initiates the combustion at higher rpm, thereby an increase in the brake power is noted.

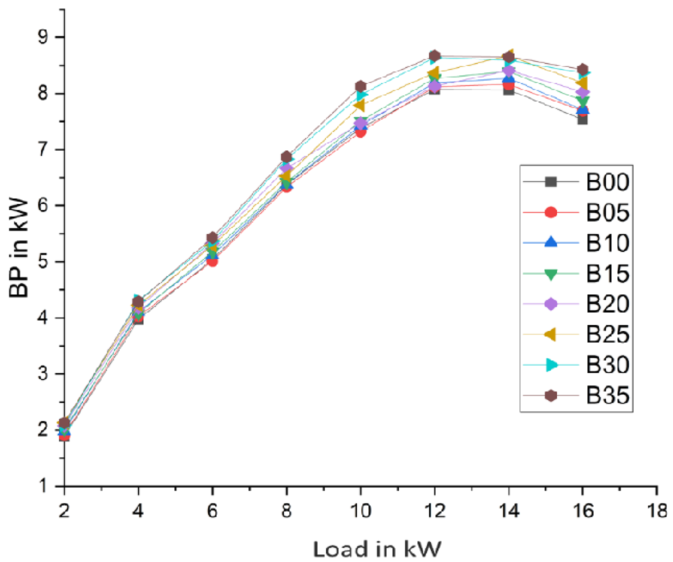

Figure 3: Influence of the n-Butanol-Gasoline Blends on the Brake Power.

4.3 Influence of the n-Butanol-Gasoline Blend on the BSFC

Brake-specific fuel consumption is the quantity of fuel an engine consumes for producing a determined amount of brake power. In the current investigation conducted on the twin spark ignition engine fueled with blends of n-butanol-gasoline, there is a decrease in the total fuel consumption. The reduction in BSFC can be seen in figure 4. With pure gasoline, the BSFC was found to be 0.227 kg/kW-h. At a speed of 3000 rpm and with B35 blend as fuel, it was seen to be 0.223 kg/kW-h, and the decrease in BSFC was found to be 1.7%. The reduction in BSFC is because of the increase in brake thermal efficiency. Initially, when the engine is started from rest, a large amount of fuel is wasted to overcome the friction. As the engine gains momentum, the necessary power required to overcome friction decreases. Thereby, the fuel consumed to produce required output decreases at rated speed.

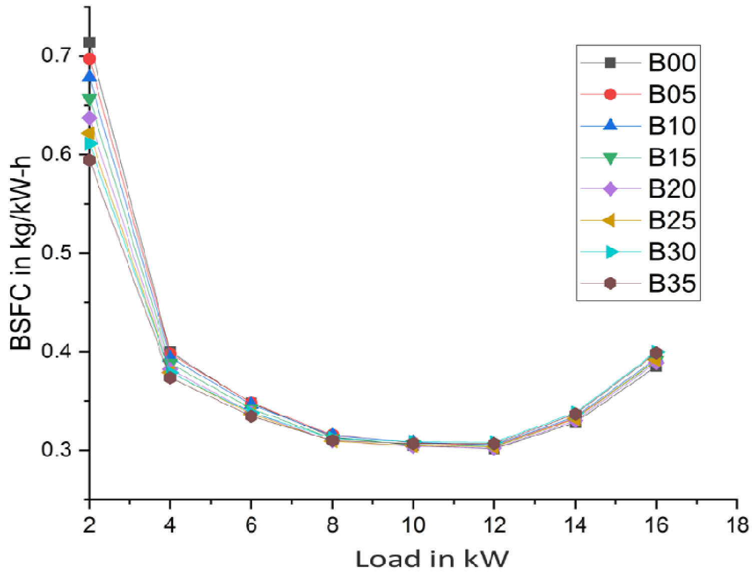

Figure 4: Influence of the n-Butanol-Gasoline Blends on the BSFC.

4.4 Influence of then-Butanol-Gasoline Blend on the Air Fuel Ratio

With the increase of n-butanol in the blend, it is found that there is a decrease in the air-fuel ratio and after a certain period, the air-fuel ratio decreases after attaining a peak value. For the engine to initially get started and move from its state of rest, a rich charge is required. This is because; all the components of the combustion chamber and the combustion chamber itself will be at a lower temperature. When the first combustion takes place, the temperature of the chamber as well as all the components would become increasingly higher than the temperature that was at rest. In such a relatively low-temperature environment for the combustion to occur, a rich mixture is very much required. As the temperature of the combustion chamber increases, a lean mixture is sufficient for producing the necessary amount of work, thus it is seen in figure 4 that with the increase, the blends percentage air-fuel ratio goes on to decrease. The air-fuel ratio with B00 was found to be 14.327 and with that of B35 was found to be 14.093. The difference in percentage was found to be about 1.6%. It reaches a maximum and then starts decreasing. The increase in the n-butanol content, the hydroxyl group present in n-butanol increases and thus the air-fuel ratio decreases with the increase in n-butanol.

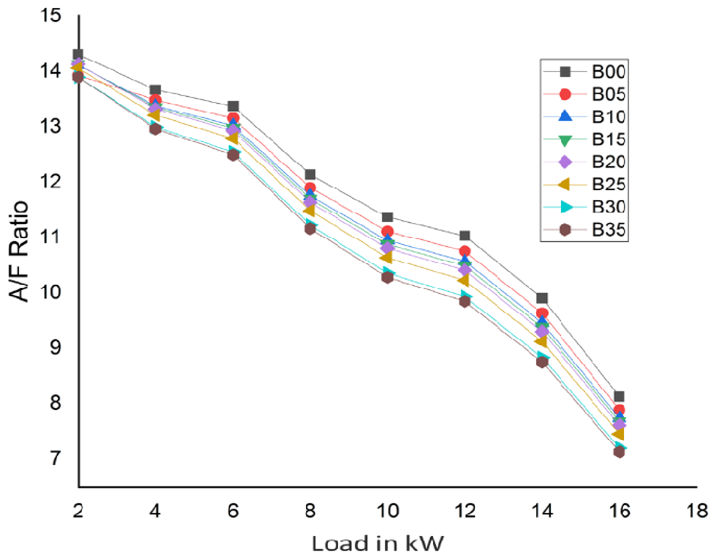

Figure 5: Influence of the n-Butanol-Gasoline Blend on the Air-Fuel Ratio.

4.5 Influence of the n-Butanol Gasoline Blends on the Brake Thermal Efficiency

Brake thermal efficiency of an internal combustion engine is defined as the amount of brake power obtained by utilizing the amount of heat released by it, on the combustion of a measured quantity of fuel. In the experimentation, brake thermal efficiency of the engine is found to increase with an increase in blends' percentage; it finds a downfall after attaining the maximum brake thermal efficiency for all the blends. The increase in brake thermal efficiency is achieved because of the complete combustion occurring in the combustion chamber. The hydroxyl group supports complete combustion by facilitating the extra oxygen required. Due to the complete combustion, the brake power produced by the engine increases and results in an increase in brake thermal efficiency of the engine. Using B00 yielded a brake thermal efficiency of 34.93% at a speed of 3000 rpm, and with B35, it is seen to be 40.384% at the same 3000 rpm, accounting to an increase of 15.6%.

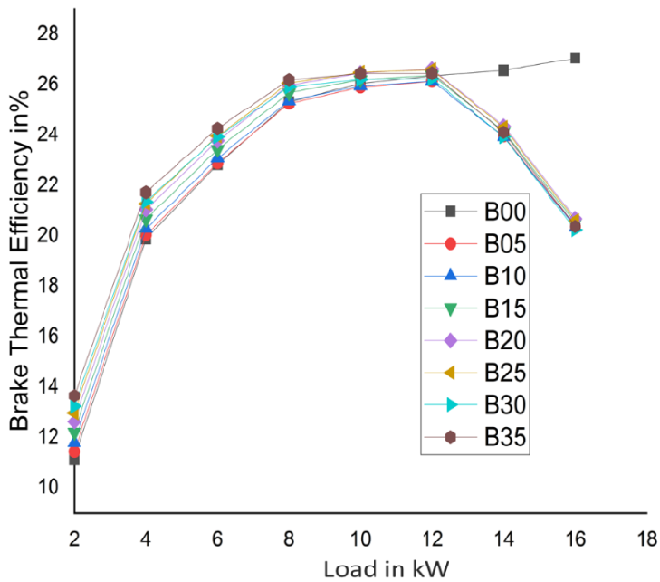

Figure 6: Influence of the n-Butanol Gasoline Blends on Brake Thermal Efficiency.

4.6 Influence of the n-Butanol-Gasoline Blends on the Volumetric Efficiency

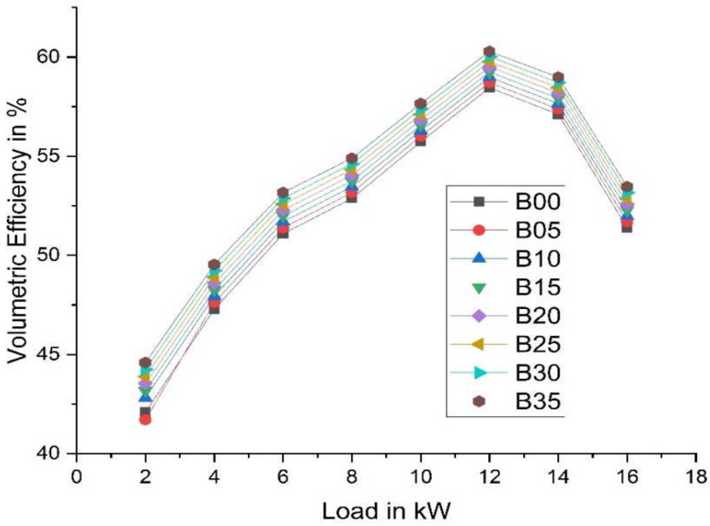

Figure 7: Influence of the n-Butanol-Gasoline Blends on the Volumetric Efficiency.

Volumetric efficiency is defined as the quantity of air-fuel mixture admitted into the invariable volume of the combustion chamber. Volumetric efficiency of the engine increases with the increase in butanol content in the blend, this is because alcohols have a higher enthalpy of vaporization. As the charge becomes cooler due to higher enthalpy, a large quantity of fuel enters the combustion chamber, increasing the volumetric efficiency. Using neat gasoline, the volumetric efficiency was found to be 43.8%, whereas the B35 blend gave an increased volumetric efficiency of 48.01%; the percentage increase in the volumetric efficiency was found to be 13.86%. Downfall is also noted after attaining the maximum volumetric efficiency for all the blends.

4.7 Influence of the n-Butanol-Gasoline Blends on the Mechanical Efficiency

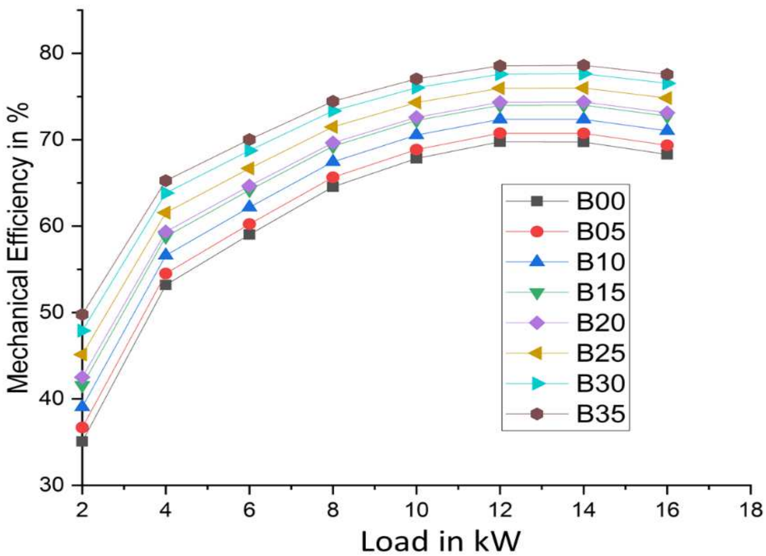

Figure 8: Influence of the n-Butanol-Gasoline Blends on the Mechanical Efficiency.

The actual power utilized by an engine from the amount of power that was actually given to an engine can be defined as the mechanical efficiency of that engine. An increase in the brake power of the internal combustion engine,; the

mechanical efficiency of that engine is also found to be increasing. The presence of a large number of the hydroxyl group in higher blends of n-butanol-gasoline and the combustion of the charge by the sparks ejected by the second spark plug during the expansion process results in complete combustion. This leads to an increase in the mechanical efficiency of the engine. The mechanical efficiency of the engine with neat gasoline was found to be 69.19%, while the mechanical efficiency of the engine with B35 blend was found to be 78.22%, thus an increase of about 13% was noted.

4.8 Influence of the n-Butanol-Gasoline Blends on the CO Emission

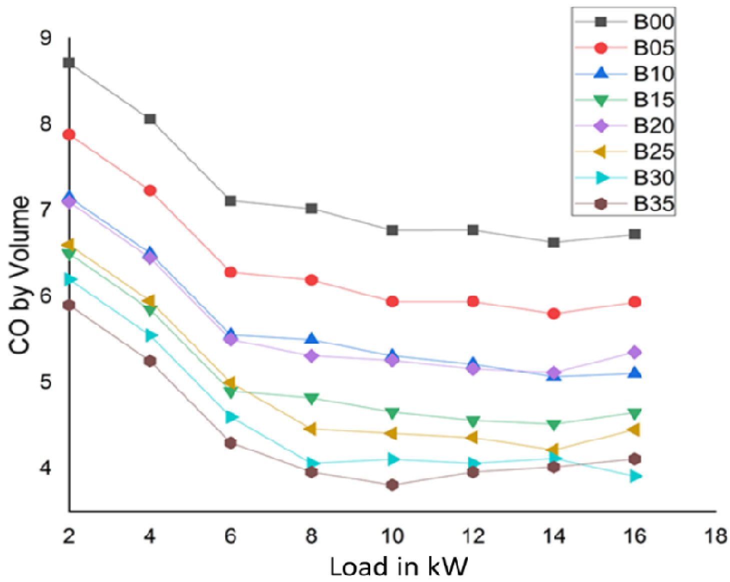

Figure 9: Influence of the n-Butanol-Gasoline Blends on the CO Emission.

Carbon monoxide is the most dangerous emission from internal combustion engines due to incomplete combustion of the supplied fuel in the combustion chamber. The measured rate of CO emission is demonstrated in figure 9. The results prove drastic decrease in CO emission with all the n-butanol blends, as compared to regular gasoline fuel. The blend B35 results in minimum CO emission at the rate of 33.32% at minimum load condition as compared to B00. With an increase in n-butanol content with blends, the concentration of CO emission was decreased with increasing load. At full load operating condition, 38.33% of lesser CO emission was recorded for B35 blends compared to pure gasoline fuel. This is to happen due to n-butanol readily comes with more oxygen content and due to lower adiabatic flame temperature during the combustion process.

4.9 Influence of the n-Butanol-Gasoline Blends on the CO_2 Emission

Figure 10 revelas that carbon dioxide emission for regular gasoline and n-butanol-gasoline blends. The results finally conclude higher CO_2 emission for B00 and lower range for n-butanol combinations. At initial loading condition, all the blends show the least carbon dioxide emission, an average of 31.94% lesser CO_2 emission from B35 blends, while comparing with regular gasoline fuel. The results indicate that at part load operating level, all combinations and B00 reveals that maximum CO_2 range, while working at maximum load CO_2 emission starts to downfall. The emissions of carbon dioxide is reduced by 31.98% at full load operating condition between neat conventional fuel and B35 blends. This is due to the optimum utilization of oxygen content to combust the supplied fuel in the combustion chamber.

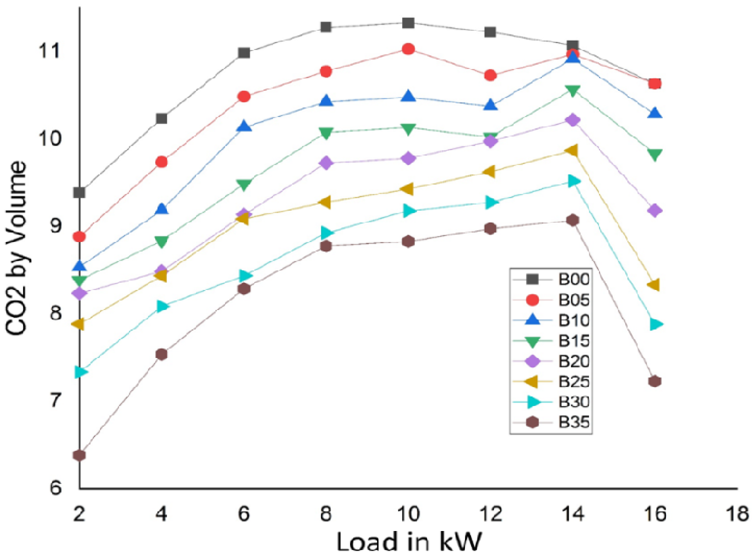

Figure 10: Influence of the n-Butanol-Gasoline Blends on the CO_2 Emission.

4.10 Influence of the n-Butanol-Gasoline Blends on the HC Emission

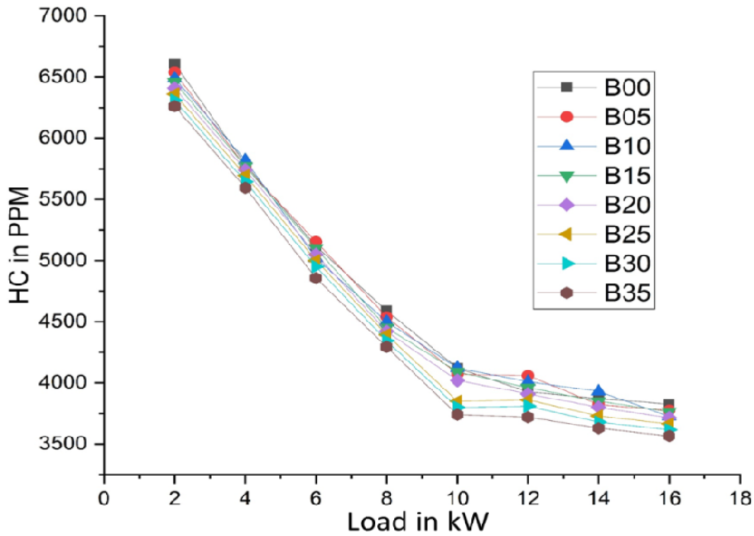

Figure 11: Influence of the n-Butanol-Gasoline Blends on the HC Emission.

Hydrocarbon emission due to unburnt fuel, which possesses insufficient air available in the combustion chamber and lesser combustion chamber temperature. Figure 11 showcased the minimum value of HC emission for variable blends as well as B00. At the least, load operational condition, has an average of 5.352% of lesser HC emission for B35 combination as compared to B00. With an increasing percentage of n-butanol with the combination indicates a drastic reduction in HC emission. Figure 11 also illustrates that with an increase in the applied load on the engine reveals HC concentration is dramatically reduced for all the blends and gasoline fuel. An average of 6.797% of HC reduction is noted for B35 at full load condition while comparing with B00.

4.11 Influence of the n-Butanol-Gasoline Blends on the NOx Emission

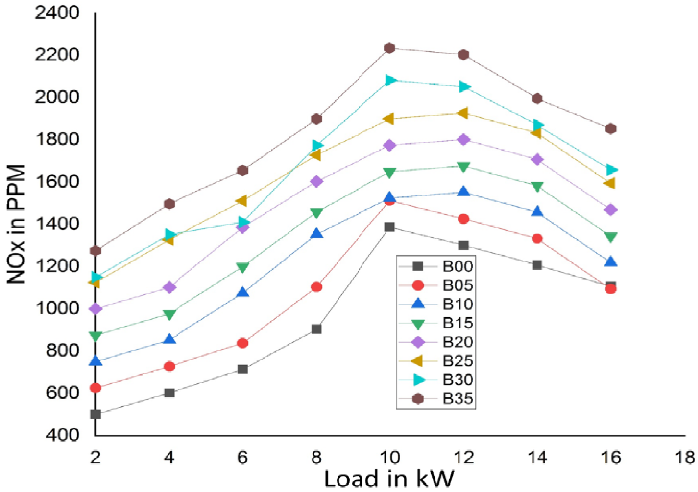

Figure 12: Influence of the n-Butanol-Gasoline Blends on the NOx Emission.

The nitrogen oxide emission takes place due to higher operation combustion chamber temperature, increase in combustion chamber temperature due to greater combustion efficiency and complete combustion of the supplied fuel and when complete combustion of the fuel is achieved during the combustion process contributes to the rising operating temperature of the engine. The higher operating temperature leads to the formation of a greater level of NOx emission. Figure 12 illustrates that the influence of n-butanol blends on NOx formation at variable load and constant operating speed. The results indicating that higher NOx emission for all the n-butanol blends as compared to B00. An average of 60% highest NOx emission for B35 at minimum load while comparing B00. At mid load, maximumNOx emission was noted, and further started to decline at full load operation.

4.12 Influence of the n-Butanol-Gasoline Blends on the O_2 Emission

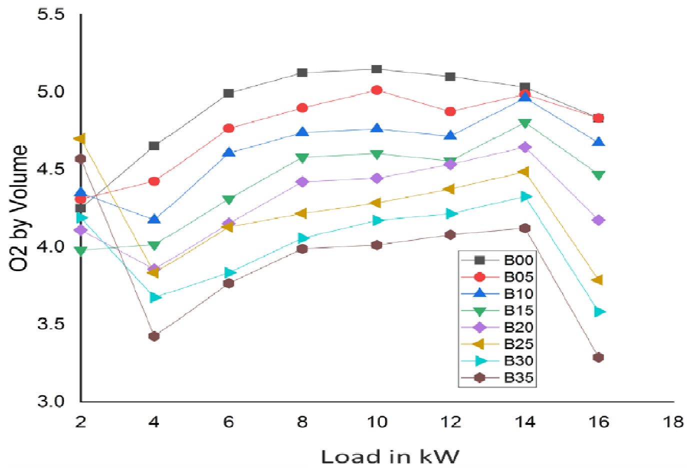

Figure 13: Influence of the n-Butanol-Gasoline Blends on the O_2 Emission.

Oxygen concentration in the exhaust system of internal combustion engine indicates lean mixture supplying to the combustion chamber and greater oxygen presence with the fuel provided. A 7% of more O2 emission were observed for B35 blends at minimum load while comparing with B00. It is evident that there is reduction in O_2 emission for all the n-

butanol blends, as compared to gasoline. The O_2 emission is reduced by 31.88% for B35 mixture at full load condition, as compared to B00. The detailed O_2 emission is showcased in figure 13.

5. CONCLUSIONS

The investigations conducted on a twin spark ignition engine; it is observed that compared to ethanol, n-butanol has better properties, such as the lower vapor pressure, higher calorific value and lesser affinity towards water. The use of B35 blends the engine brake power and brake thermal efficiency and increases volumetric efficiency. The brake-specific fuel consumption is gradually decreased, and thus the amount of fuel required to produce a known amount of work is reduced. The emission characteristics such as carbon monoxide, carbon dioxide and hydrocarbon emission were reduced for all the n-butanol blends, while compared with clean gasoline fuel. The nitrogen oxides and oxygen emission were increased for n-butanol blends at all the operating condition. The experimental results indicating that the use of the twin spark plug and adding of n-butanol with gasoline fuel was found to be useful in increasing the engine efficiency and minimum CO, CO_2 and HC emission with all the percentage of fuel blends that were not utilized in a single-spark ignition engine.

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AUTHORS' PROFILE

Ravikumar, R., BE, M. Tech, (PhD), Assistant Professor & Research Scholar. He obtained his Bachelor of Engineering in Mechanical Engineering from Secab Institute of Technology, Vijayapur in the year of 2010. Obtained his Master's degree in Thermal Power Engineering from Bapuji Institute of Technology, Davanagere in the year of 2012. He has published 11 International/National peer-reviewed research articles and presented research findings in many International/National conferences. He has more than seven years of academic experience. Currently, pursuing his research work on alternative fuels and internal combustion engines to investigate the performance and emission characteristics by using various alternative fuels, the engine will be operated by varying compression ratio, speed and load with different blends of derived fuels and conventional diesel. A lifetime member of ISME, Fund received from Govt. and non–Govt. agencies worth 3 lakhs. His ambition is to bring out better efficient alternative biofuel for IC engines in terms of better performance and lower emissions. Currently, he and his team working on engine combustion by utilizing biofuels derived from various waste sources, such as waste plastics, used tyres, chicken waste skin, pig waste, etc., by simulation as well as experimental methods.

Dr. Antony A. J., B.Tech., M.Sc. Engg. , Ph.D. Principal. Dr. Antony. A. J. obtained his B.Tech in Mechanical Engineering degree from NITK Surathkal (Mysore University) in the year 1979. He obtained his master's degree from NITK Surathkal (Mysore University) in the year 1988. He did his Ph.D. from NITK Surathkal under Mangalore University, in the year 1996. He has published 11 papers in International & National Journals. He has presented many research articles in National & International conferences. He has presented papers in the International conference at the Institute of Petroleum, Abu Dhabi, Imperial College London, UK, International conference at Las Vegas, United States of America. He has successfully guided four Ph.D.s. Two research scholars have submitted the Ph.D. thesis under his guidance. Presently, three candidates are pursuing Ph.D. under his guidance. Before joining Mangalore Marine College & Technology as principal, Dr. Antony, A. has worked at different positions at reputed institutes. Professor & Head of the Department at Sri Siddhartha Institute of Technology, Tumkur, St. Joseph Engineering College, Vamanjoor, Vice Principal at Sahyadri College of Engineering & Management, Mangalore, Dean at P. A. College of Engineering, Mangalore, Principal at Bearys Institute of Technology, Mangalore etc. He was the member of Local Investigation Committee, BOE, Board of Studies, Research Centre recognition committee of Vishveshwaraya Technological University, Karnataka.